Influence of the coaching condition on the magnitude and reliability of drop jump height in men and women

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ABSTRACT

This study examined the effect of different coaching conditions on the magnitude and reliability of drop jump height in men and women. Nineteen collegiate sport sciences students (10 men) performed 2 sets of 10 drop jumps under four different coaching conditions: neutral (NE), augmented feedback (AF), external focus of attention (EF), and combination of AF and EF. The AF condition revealed a significantly higher jump height than the NE condition (p = .002), while no significant differences were observed for the remaining conditions ($p \geq .38$). The EF condition was more reliable than the NE and AF conditions ($CV_{ratio} \geq 1.15$), while no differences were observed between the remaining conditions. These results suggest that both the magnitude and reliability of the drop jump height performance is influenced by the coaching condition.

Keywords: augmented feedback, focus of attention, plyometric.

INTRODUCTION

Jump height is a key variable for successful participation in most athletic activities (Miura, Yamamoto, Tamaki, & Zushi, 2010; Sattler, Hadzic, Dervisevic, & Markovic, 2015). In team sports, the ability to jump higher and faster than an opponent can be advantageous in competition (e.g., attacking and blocking in volleyball, or shooting and rebounding in basketball), while in individual sports it could be decisive to win a competition (e.g., high jump). In this regard, improving vertical jumping ability is one of the primary objectives for coaches and strength and conditioning professionals (Sanchez-Sixto, Harrison, & Floria, 2018). Plyometric training, which is characterised by rapid stretch-shortening cycle muscle actions (Cormie, McGuigam, & Newton, 2011), is a well-known modality to improve jumping performance (Markovic, 2007). The stretch-shortening cycle is a natural action, during which muscles are powerfully contracted immediately after being rapidly stretched (Comyns, Brady, & Molloy, 2019). The drop jump (DJ) is one of the plyometric exercises most commonly used to enhance an athlete's performance as well as to asses injury risk (Collings, Gorman, Stuelcken, Mellifont, & Sayers, 2019; Prieske et al., 2019). The DJ can be performed using different jumping strategies, which substantially affects both kinematic and kinetic variables (Mrdakovic, Ilic, Jankovic, Rajkovic, & Stefanovic, 2008; Struzik, Juras, Pietraszewski, & Rokita, 2016). For example, a bounce DJ aims to reverse the downward velocity into an upward one as soon as possible after landing, whereas a countermovement DJ is aimed at achieving the highest possible jump height by means of a larger downward movement upon landing (Struzik et al., 2016). The drop-height and eccentric loading are probably the two most studied methodological issues in order to maximise DJ performance (Asmussen & Bonde-Petersen, 1974; Bridgeman, McGuigan, Gill, & Dulson, 2017; Markovic, Vuk, & Jaric, 2011; Prieske et al., 2019). Moreover, one factor that may acutely affect physical performance (i.e., jump height) is the various forms of instruction or feedback (i.e., both forms will be referred to as 'coaching conditions' in the further text) given to the participant during the DJ testing protocols (Brady, Comyns, Harrison, & Warrington, 2017; Wulf, 2013). However, despite the widespread use of the DJ, the impact of different coaching conditions on DJ performance still warrants further investigation.

Coaching conditions play a vital role in both motor learning and physical performance (Brady et al., 2017; Schmidt & Lee, 1999; Schmidt & Wulf, 1997; Wulf, 2013). Augmented feedback (AF) has been defined as feedback from an external source that pertains to previous results or performance (Brady et al., 2017). Previous work has shown the immediate and long-term benefits of providing AF on DJ performance compared to a neutral condition (NE) (Keller, Lauber, Gehring, Leukel, & Taube, 2014). The underlying mechanism of these performance gains is mainly related to motivational factors (Keller et al., 2014). Specifically, the provision of AF is believed to enhance the intrinsic motivation by encouraging participants to outplay their foregoing or maximal performance (Wälchli, Ruffieux, Bourquin, Keller, & Taube, 2016). Moreover, focusing a participant´s attention internally or externally has also been deemed an effective approach when optimising DJ performance (Byrne, Moody, Cooper, Lawlor, & Kinsella, 2018; Comyns et al., 2019; Khuu, Musalem, & Beach, 2015; Oliver, Barillas, Lloyd, Moore, & Pedley, 2019). Specifically, an external focus of attention (EF), where the participant directs their attention toward the effects of the movement on the environment, was superior or more effective than a NE or internal focus of attention (IF; i.e., where their attention is directed toward the body parts that are involved in the movement) (Comyns et al., 2019). The performance gains associated with an EF are attributed to the constrained action hypothesis which suggests that the movements are controlled by automatic motor processes when adopting an EF (Wulf, 2013). To the best of our knowledge, only two previous studies have compared the effects of AF and EF on vertical jump performance (Keller, Lauber, Gottschalk, & Taube, 2015; Wälchli et al., 2016). During the countermovement jump (CMJ), Keller et al. (2015) reported that the AF provided a higher performance than EF and IF. Similarly, Wälchli et al. (2016) observed a superior CMJ performance when combining AF and EF (AF+EF) compared to other coaching conditions (i.e., NE, AF, monetary reward, and other combinations). However, the impact of different coaching conditions (e.g., AF, EF or AF+EF) on exercises which require a high level of reactive strength (e.g. the DJ) has not yet been investigated. Similarly, there is still limited evidence comparing the benefits of different coaching conditions between men and women. For example, Walsh, Waters, & Kersting (2007) found that high-level women basketball players responded differently to jumping/landing instructions than high-level men basketball players. Specifically, women showed a greater inward movement of the knees during landings and also demonstrated lower absolute impact forces, while men did not reveal any change in landing parameters. Therefore, of special interest would also be exploring whether possible differences in DJ performance between coaching conditions could be dependent on participant sex. Moreover, if DJ performance is altered with different coaching conditions, then the reproducibility of the performance must be considered. It is widely believed that motor control is optimised to achieve an accuracy and efficiency performance, while the variability that interferes with this goal should be minimized or countered. In this regard, task-relevant coaching conditions may allow to correct errors in the brain's internal model for optimising motor control strategies and performance, while those "planning errors" could accumulate in the absence of certain coaching conditions (Dhawale, Smith, & Ölveczky, 2017). Furthermore, by determining the DJ height performance reproducibility, practitioners can be confident in knowing that any performance related changes are due to interventions rather than biological variation or technical error (Fernandes, Lamb, & Twist, 2016; Fernandes et al., 2018). Therefore, it is also essential to know whether the beneficial effects persist over multiple sets to determine the transfer to applied settings.

To address the gaps raised above, the present study attempted to identify the coaching condition which could be used to maximise jumping performance. Specifically, the aim of this study was to examine the effect of four different coaching conditions (i.e., NE *vs.* AF *vs.* EF *vs.* AF+EF) on the magnitude and reliability of DJ height performance in men and women. We hypothesised that (I) the highest jump height would be achieved for the AF+EF condition, followed by the AF condition, and finally EF condition (Keller et al., 2015; Wälchli et al., 2016), (II) the EF would be the most reliable coaching condition because it promotes automaticity in movement control (Wulf, 2013), and (III) the magnitude and reliability of the DJ height performance would differ between men and women (Walsh et al., 2007).

MATERIALS AND METHODS

Participants

Nineteen sport science students, 10 men (age: 20.5 ± 2.2 years; height: 1.76 ± 0.61 m; body mass: 70.7 ± 10.6 kg) and 9 women (age: 19.2 ± 1.6 years; height: 1.61 ± 0.51 m; body mass: 56.6 ± 7.3 kg), volunteered to participate in this study (data are presented as mean ± standard deviation [SD]). All participants had prior resistance training experience (3.3 ± 1.4 years) and were familiar with the DJ exercise. However, none of them included jumping as part of their habitual training routines. No physical limitations, health problems or musculoskeletal injuries that could compromise testing were reported. All participants were informed of the study procedures and signed a consent form prior to initiating the study. The study protocol adhered to the tenets of the Declaration of Helsinki and was approved by the Institutional Review Board (IRB approval: 687/CEIH/2018).

Design

A randomised crossover design was used to investigate the effect of different coaching conditions on the magnitude and reliability of DJ height performance in men and women. In a single session, participants performed 2 sets of 10 DJs for each condition (i.e., NE, AF, EF, AF+EF) (80 jumps). The order of the coaching conditions was randomised across participants. At the beginning (i.e., after warm-up) and the end (i.e., before cooldown) of the session, 3 CMJs were performed to quantify the extent of fatigue induced by the testing protocol (García-Ramos, Pérez-Castilla, & Jaric, 2018). Jump height performance was measured using an optoelectronic measurement system (Optojump, Microgate, Bolzano, Italy). Participants were asked to avoid any strenuous exercise 72 h before testing. The testing session was conducted at the University's research laboratory under the direct supervision of the same investigator, at similar time of day for all participants (± 1 h), and under similar environmental conditions (≈22º C and ≈60% humidity).

Testing procedures

Testing began with a standardised warm-up consisting of 5 min of jogging, followed by joint mobility exercises, and 1 set of 6 submaximal DJs. After warm-up, participants rested for 3 min and then completed 3 unloaded CMJs separated by 1 min. Thereafter, participants performed 2 sets of 10 maximal DJs under each of the following conditions: NE, AF, EF, and AF+EF. The coaching condition was verbally given to the participants before the start of each set and repeated before every jump (**Table 1**). The jump height was visually displayed on a television screen immediately after each repetition during the AF and AF+EF conditions. For the EF and AF+EF conditions, a soccer ball was attached to the ceiling and participants were instructed to touch the ball with their heads when ascending (**Figure 1**). The height of the ball was individually adjusted for each participant to ≈ 5 cm above the head apex (Keller et al., 2015). The rest period between successive jumps and training sets was set to 15 s and 4 min, respectively. After the completion of the final DJ set, participants rested for 3 min and performed 3 more unloaded CMJs separated by 1 min. The level of fatigue induced by the testing procedure was assessed by comparing the trial with the highest CMJ height at the beginning and at the end of the session (García-Ramos, Pérez-Castilla, & Jaric, 2018). A decrease of -1.1 ± 1.5 cm (-3.5%, Cohen's *d* effect size [*d*] = 0.13) in CMJ height was observed after the testing procedure (**Figure 2**).

[Table 1]

[Figure 1]

[Figure 2]

The DJ technique involved the participants standing on a 50 cm box with the knees and hips fully extended, feet approximately shoulder-with apart, and hands placed on the hips. Participants were then asked to step off the box with the dominant leg, drop down to land evenly on both feet and jump-off ground at maximal-effort to perform a bilateral vertical jump (Prieske et al., 2019). Specifically, participants were required to perform a countermovement DJ technique that would achieve the highest possible jump height by means of a self-preferred optimal knee flexion and a fast countermovement (Struzik et al., 2016). A 50 cm drop height was used based on the optimal dropping height (40-60 cm) previously reported in a similar population (Asmussen & Bonde-Petersen, 1974; Komi & Bosco, 1978). Participants were required to land between the Optojump bars with extended feet, ankles, knees, and hips.

Measurement equipment and data acquisition

Body height (Seca 202, Seca Ltd., Hamburg, Germany) and body mass (Tanita BC 418 segmental, Tokyo, Japan) were assessed at the beginning of the testing protocol. Jump height was estimated from the flight time recorded by an optoelectronic measurement system (Optojump, Microgate, Bolzano, Italy), which consists of 2 transmitting and receiving bars (100 cm × 8 cm; ≈1 m apart) interfaced with a personal computer. A high validity and reliability of the jump height estimated by Optojump has been reported elsewhere (Rago et al., 2018).

Statistical analysis

Data are presented as mean ± SD. The normal distribution of the data was confirmed by the Shapiro-Wilk test ($p > .05$). A mixed repeated-measures analysis of variance (ANOVA) with the 'coaching condition' (i.e., NE *vs.* AF *vs.* EF *vs.* AF+EF) as within-participants factor, and 'participant's sex' (i.e., men *vs.* women) as between-participants factor, was used to evaluate differences in DJ height performance. It should be note that the 'training set' was previously included in the mixed repeated-measures ANOVA as within-participants factor. However, since no significant main effect was observed for the 'training set' (i.e., 1st and 2nd) and their interaction also did not reach statistical significance ($p > .05$), we decided to use the average value of all trials performed in each coaching condition (i.e., 2 sets × 10 repetitions) for statistical analyses. Post hoc tests were performed by means of Bonferroni procedures when appropriate for multiple comparisons. Partial eta-squared (η_p^2) was calculated for the ANOVA where the values of the effect sizes 0.01, 0.06 and above 0.14 were considered small, medium, and large, respectively (Cohen, 1988). The magnitude of the differences was also expressed as standardised mean difference (Cohen´s *d* effect size, *d*). The criteria to interpret the magnitude of the *d* was as follows: *negligible* (< 0.20), *small* (0.20-0.50), *moderate* (0.50-0.80) and *large* (> 0.80) (Hopkins, Marshall, Batterham, & Hanin, 2009). Reliability was assessed by the coefficient of variation (CV) and the intraclass correlation coefficient (ICC; model 3,1) with the corresponding 90% confidence interval (CI). Acceptable reliability was determined as a CV < 10% and ICC > 0.70 (Cormack, Newton, McGuigan, & Doyle, 2008). To interpret the magnitude of differences between 2 CVs, a criterion for the smallest important ratio was established as higher than 1.15 (García-Ramos, Feriche, Pérez-Castilla, Padial, & Jaric, 2017). Reliability analyses were performed by means of a custom spreadsheet (Hopkins, 2000), while other statistical analyses were performed using the software package SPSS (IBM SPSS version 22.0, Chicago, IL, USA). Statistical significance was accepted at $p < .05$ level.

RESULTS

The ANOVA revealed a significant main effect for the 'coaching condition' (F(3,51) = 3.08, $p = .04$, $\eta_p^2 = .15$), while the interaction 'coaching condition × participant's sex' did not reach statistical significance (F(3,51) = 2.38, $p = .08$, $\eta_p^2 = .12$). The AF condition revealed a significantly higher DJ height performance compared the NE condition ($t(18) = -3.93$, $p < .01$, $d = 0.14$), while no significant differences were observed between the remaining coaching instructions ($t(18)$ from -1.96 to 1.34, $p \geq .38$, $d \leq 0.10$) (**Figure 3**).

[Figure 3]

Negligible differences ($d \leq 0.12$) were observed for the DJ height performance between both training sets with the main exception of the men during the NE condition ($d = 0.28$) (**Table 2**). An acceptable reliability (CV ≤ 5.83% and ICC ≥ .97) was observed for DJ height in all coaching conditions. The DJ height obtained following the EF condition was more reliable than the NE and AF conditions (CV_{ratio} = 1.24 and 1.15, respectively), while no differences in reliability were observed between the remaining coaching conditions. Regarding sex, only DJ height obtained during AF+EF condition was more reliable for men than women (CV_{ratio} = 1.20).

[Table 2]

DISCUSSION

This study sought to explore the effect of different coaching conditions on the magnitude and reliability of DJ height performance in men and women. These findings indicate that both the magnitude and reliability of the performance outcome was influenced by the coaching condition. Rejecting our hypothesis, the use of the AF+EF did not provide the highest DJ height. Instead the AF condition provided a higher DJ height compared to the NE condition in both men and women, while no significant differences were observed between the AF, EF, and AF+EF conditions. On the other hand, although all coaching conditions showed acceptable reliability outcomes, the EF condition was more reliable than the NE and AF conditions. These results suggest that the different coaching conditions can be used to maximise the DJ height performance in successive training sets.

The use of different coaching conditions is deemed a suitable training approach for the maintenance of training quality during a session (Byrne et al., 2018). Since it has been previously demonstrated the largest enhancements in CMJ performance when providing AF along with EF (Wälchli et al., 2016) as well as a higher CMJ performance for AF compared to EF (Keller et al., 2015), we hypothesised that the best performance outcome would be achieved for the AF+EF condition, followed by the AF condition, and finally EF condition. Contrary to our hypothesis, no significant differences were observed between the different coaching conditions (i.e., AF, EF, and AF+EF). Our results are in line with those recently demonstrated by Keller, Kuhn, Lüthy, & Taube (2018) who found no additional benefit on service speeds or speed-accuracy trade-off for AF+EF condition compared to NE, AF, EF, and IF in high-level national tennis players. It is plausible that complex motor tasks require attention recourses that may interfere with the parallel processing of too much information (Keller, Kuhn, Lüthy, & Taube, 2018). It is important to noted that, although subjects were familiar with the task, the DJ exercise can be described as a complex movement as feed-forward and feedback control takes place to control multiple degrees of freedom (Keller et al., 2014). This could explain, at least in part, the fact that the AF+EF condition did not reveal the highest DJ performance. In this context, it has been speculated that AF and EF depend on different mechanics (Wälchli et al., 2016). On one hand, the AF can enhance the intrinsic motivation and competitiveness of participants in an attempt to outplay an objective value (Keller et al., 2014; Schmidt & Lee, 1999; Weakley et al., 2019). Previous research has shown that the immediate DJ performance drops as soon as AF is removed and, therefore, AF seems to act on motivation rather than on learning in the short-term (Keller et al., 2014). On the other hand, the EF results in a more efficient movement execution based on the constrained action hypothesis, which stated that movement are more controlled by automatic motor processes (Wälchli et al., 2016; Wulf, 2013). More specifically, our results corroborate with previous work by Comyns et al. (2019) who did not find significant difference in the DJ height performance between the NE, IF and EF conditions. Consistent with Keller et al. (2014) observations, only the use of AF resulted in a better DJ height compared to the use of an NE condition. Therefore, it is reasonable to speculate that the absence of beneficial effects for EF and AF+EF conditions compared to the NE condition could be attributed to the fact that the participants, not being experts in this task, needed more trials (Schmidt & Lee, 1999) or time (e.g., a delay of more than 15 s) (Swinnen, Schmidt, Nicholson, & Shapiro, 1990) to optimally process intrinsic feedback. Collectively, the current study provides support that the use of AF as a useful tool to increase motor performance in the short-term due to possible enhance of intrinsic motivation and competitiveness (Brady et al., 2017; Weakley et al., 2019; Wulf, 2013). According to the Cognitive evaluation theory, the social-contextual events that conduct toward feeling of competence, autonomy or relatedness during action can enhance intrinsic motivation for that action (Ryan & Deci, 2000). It should be note that the principles of Cognitive evaluation theory are generally applied for activities that hold intrinsic interest for individuals, that is, activities that have the appeal of novelty, challenge, or aesthetic value for examples.

The beneficial effects of providing different forms of coaching conditions over single training sets have been widely reported in literature (Comyns et al., 2019; Keller et al., 2015; Khuu et al., 2015; Wälchli et al., 2016). However, to our knowledge, it is unknown which of the coaching conditions is able to provide the best reliability during DJ performance over consecutive training sets. The current study shows that the performance outcome was highly consistent for all coaching conditions. Supporting our second hypothesis, the EF condition was significantly more reliable than the NE and AF conditions. Since participants in the present study were not experts, but they were already familiar with the requested movement, the highest reliability for EF condition could likely be explained by a certain automaticity in movement control (Wälchli et al., 2016; Wulf, 2013). On the other hand, it is plausible that the effects observed for AF condition were related to the initial novelty of providing visual feedback on the television screen, and therefore the positive effects may be slightly mitigated with repeated exposure in successive training sets (see Table 2) as well as to the slightly influence of fatigue as consequence of the higher effort made in the successive repetitions. Conversely, the lower reliability outcomes observed during the NE condition may be due to high variability reported in the DJ height measurements throughout the course of the training sets. Nonetheless, the present findings suggest that the possible beneficial effects of coaching conditions are highly consistent between successive training sets. Importantly, practitioners can use multiple sets of an exercise within a training session, and, therefore, coaching conditions may be a more advantageous training approach in producing a more consistent performance. Moreover, this consistency indicates that, when using different coaching conditions, practitioners can use the DJ to monitor changes in athletic performance with confidence. These results are in line with previous studies that have been conducted to explore the reliability of vertical jump performance when AF is provided immediately after each jump. For example, García-Ramos et al. (2020) observed that the provision of AF about the jump height during vertical jump testing is effective to enhance vertical jump performance but it does not reduce the variability in jumping performance. Randel, Cronin, Keogh, Gill, & Pedersen (2011) found that the provision of AF was beneficial to increase the consistency of velocity performance during jump squats performed over 3 consecutive sessions. Finally, it is also important to note that Keller et al. (2014) observed a greater improvement in DJ height when participants received AF about their jump height in 100% (+14%), 50% (+10%), and 0% (+6%) of the jumps after 4-weeks of DJ training despite the withdrawal of AF during post-testing. Therefore, these results contradict the "guidance hypothesis", which dictates that high relative frequency of AF guides learners to optimize performance but at the same time participants can become dependent on AF with difficulty in maintaining performance or retaining any form of learning effects when AF is withdrawn (Keller et al., 2014; Salmoni, Schmidt, & Walter, 1984). Participants may not be dependent on AF in already acquired complex motor task. However, future research needs to assess long-term physical adaptations and retentions from other coaching strategies on DJ performance.

Previous studies have investigated the effect of different coaching conditions on DJ performance using only men participants (Comyns et al., 2019; Khuu et al., 2015; Oliver et al., 2019), raising the question of whether similar effects could be observed in women. To our knowledge, only one study has examined whether the effects of two simple verbal instructions on landing mechanics differ between men and women (Walsh et al., 2007). The latter found differences between high-level women and men basketball players in landing mechanics after receiving the same instructions. Specifically, women reduced their frontal plane knee alignment and impact force maximum after instruction, while men did not reveal any change in landing parameters. In contrast, rejecting our third hypothesis, we revealed a similar response of both sexes using different coaching conditions in order to optimise the DJ height performance. In addition, an acceptable and similar reliability was observed for all coaching conditions in both sexes, with the only exception of the AF+EF condition that was more reliable for men. Our results suggest that the beneficial effects observed for the different coaching conditions on DJ height are independent of the sex. Future studies should clarify whether our findings could be applicable to other vertical jump exercises commonly used during plyometric training.

Finally, several limitations of the present study should be acknowledged. Firstly, the fact of including a relatively small sample size with a variety of training backgrounds may have confounded our findings. It is well documented that highly trained athletes can recruit a greater relative percentage of motor units than their lesser trained counterparts (Van Cutsem, Duchateau, & Hainaut, 1998). Future studies should explore whether training background may influence the response to coaching conditions. Secondly, although all participants were familiar with the DJ exercise as a part of their academic curriculum, it is possible that more trials and leaning sessions may be necessary to beneficiate more from the coaching conditions (Schmidt & Lee, 1999). Thirdly, despite the fact that the level of neuromuscular fatigue induced by the testing procedure was evaluated from the jump height loss, the impact of mental fatigue on physical performance was not taken into consideration (Marcora, Staiano, & Manning, 2009). However, we decided to implement the coaching conditions in a randomised order across participants to reduce as much as possible the influence of mental fatigue on the main findings of the present study (i.e., comparison between coaching conditions). Finally, we did not analyse whether the coaching condition affects the DJ execution strategy (i.e., contact time) (Comyns et al., 2019). Previous studies have reported that although vertical jump technique can change during a training session, jump height performance does not seem to affected by these changes (Chandler, Greig, Comfort, & McMahon, 2018). Future studies should provide more comprehensive insight into the influence of coaching condition on biomechanical variables related to DJ performance.

CONCLUSIONS

Our results indicate that both the magnitude and reliability of the DJ height performance is influenced by the coaching condition. Specifically, the AF condition provided a higher DJ height compared to the NE condition in both men and women, while no significant differences were observed between the AF, EF, and AF+EF conditions. In addition, although all coaching conditions showed acceptable reliability outcomes, the EF condition was more reliable than the NE and AF conditions. Therefore, it appears that the different coaching conditions can maximise DJ height performance in both sexes. However, each coaching condition may be preferable depending on various surroundings. For example, providing knowledge of results through an external source (e.g., AF or AF+EF) may be the preferable approach in sport settings where there is a small group of athletes training at the same time. The use of technology may require an additional technical support from the coach, while the use of EF could be more appropriate when the coach does not have available any technology.

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FIGURE CAPTIONS

Figure 1. Experimental setup including (a) 50-cm height box, (b) soccer ball attached to the ceiling, (c) television screen placed in front of the participant, and (d) optoelectronic measurement system. This setup was used for the augmented feedback + external focus condition.

Figure 2 – Individual changes in jump height after the drop jump testing protocol. *d*, Cohen's *d* effect size ([CMJ-pre – CMJ-post]/SD both); %Δ, percentage differences ([CMJ-pre – CMJ-post]/CMJ-post x 100). Data are mean ± error standard of measurement.

Figure 3. Individual comparisons of the drop jump height performance between different coaching conditions. NE, neutral; AF, augmented feedback; EF, external focus of attention. *, significant differences between the AF and NE conditions ($p < .05$; ANOVA with Bonferroni correction). Data are mean ± error standard of measurement.

Table 1. Verbal instructions given to the participants during the testing protocol for each coaching condition.

Coaching conditions	Verbal instructions
NE	"Jump as high as possible with a fast countermovement"
AF	"When you attempting to jump as high as possible with a fast countermovement, I want you to maximise the number on the screen indicating your jump height"
EF	"When you attempting to jump as high as possible with a fast countermovement, I want you to focus your attention on jumping as close to the ball as you possibly can"
AF+EF	"When you attempting to jump as high as possible with a fast countermovement, I want you to focus your attention on jumping as close to the ball as you possibly can and maximise the number on the screen indicating your jump height"

NE, neutral; AF, augmented feedback; EF, external focus of attention.

Table 2. Reliability of the jump height obtained from different coaching conditions in the drop jump exercise.

Condition	Sex	Set 1 (mean ± SD, cm)	Set 2 (mean ± SD, cm)	*d*	CV (90% CI)	ICC (90% CI)
NE	Men	33.4 ± 5.5	33.4 ± 4.6	0.00	5.52 (4.95-6.26)	.87 (.82-.90)
	Women	22.1 ± 3.8	22.0 ± 4.0	0.03	5.83 (5.20-6.66)	.89 (.85-.92)
	Total	28.1 ± 7.4	28.0 ± 7.2	0.01	5.71 (5.27-6.24)*	.95 (.94-.90)
AF	Men	35.9 ± 5.8	34.3 ± 5.4	0.28	5.01 (4.49-5.68)	.90 (.87-.93)
	Women	22.5 ± 3.5	22.3 ± 3.9	0.06	4.74 (4.23-5.42)	.92 (.89-.94)
	Total	29.6 ± 8.3	28.6 ± 7.7	0.12	5.29 (4.88-5.79)*	.96 (.95-.97)
EF	Men	34.9 ± 5.7	34.7 ± 5.2	0.05	4.37 (3.91-4.95)	.92 (.89-.94)
	Women	21.9 ± 4.4	21.4 ± 4.2	0.11	4.88 (4.35-5.57)	.94 (.92-.96)
	Total	28.7 ± 8.3	28.4 ± 8.1	0.04	4.62 (4.26-5.05)	.97 (.97-.98)
AF+EF	Men	35.0 ± 5.7	34.6 ± 5.5	0.07	4.74 (4.25-5.37) †	.91 (.88-.94)
	Women	22.2 ± 4.0	22.1 ± 3.8	0.03	5.68 (5.06-6.48)	.90 (.86-.93)
	Total	28.9 ± 8.1	28.7 ± 7.9	0.03	5.12 (4.73-5.60)	.97 (.96-.97)

NE, neutral; AF, augmented feedback; EF, external focus of attention; SD, standard deviation; *d*, Cohen's *d* effect size ([higher value – lower value]/SD both]); CV, coefficient of variation; intraclass correlation coefficient; 90% CI, 90% confidence interval. Significant differences are determined as a CV_{ratio} higher than 1.15. *, significantly less reliable than EF condition; †, men significantly more reliable than women.

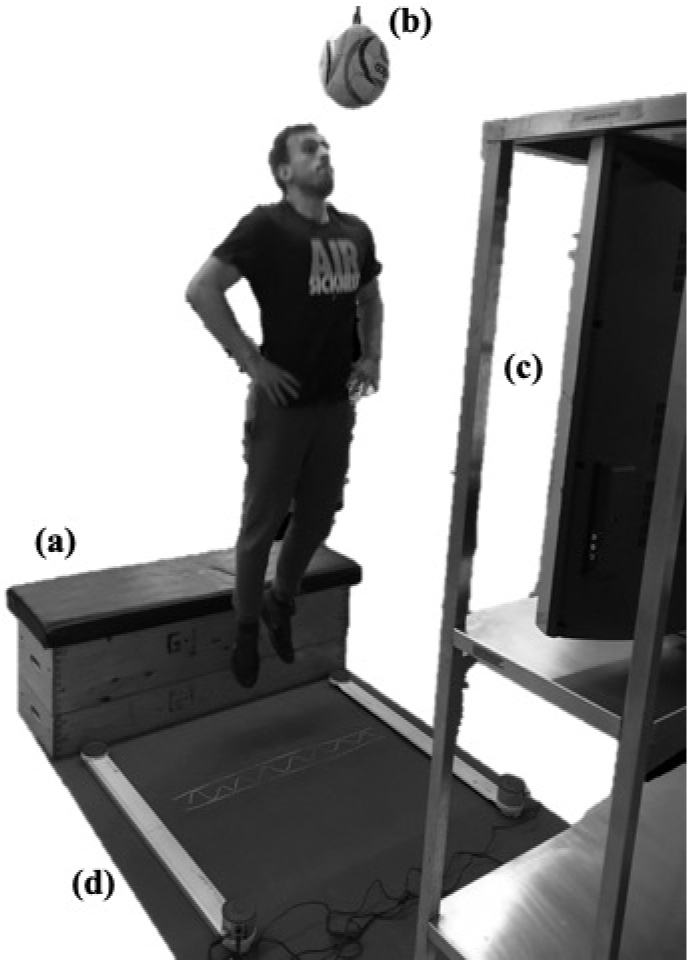

Figure 1. Experimental setup including (a) 50-cm height box, (b) soccer ball attached to the ceiling, (c) television screen placed in front of the participant, and (d) optoelectronic measurement system. This setup was used for the augmented feedback + external focus condition.

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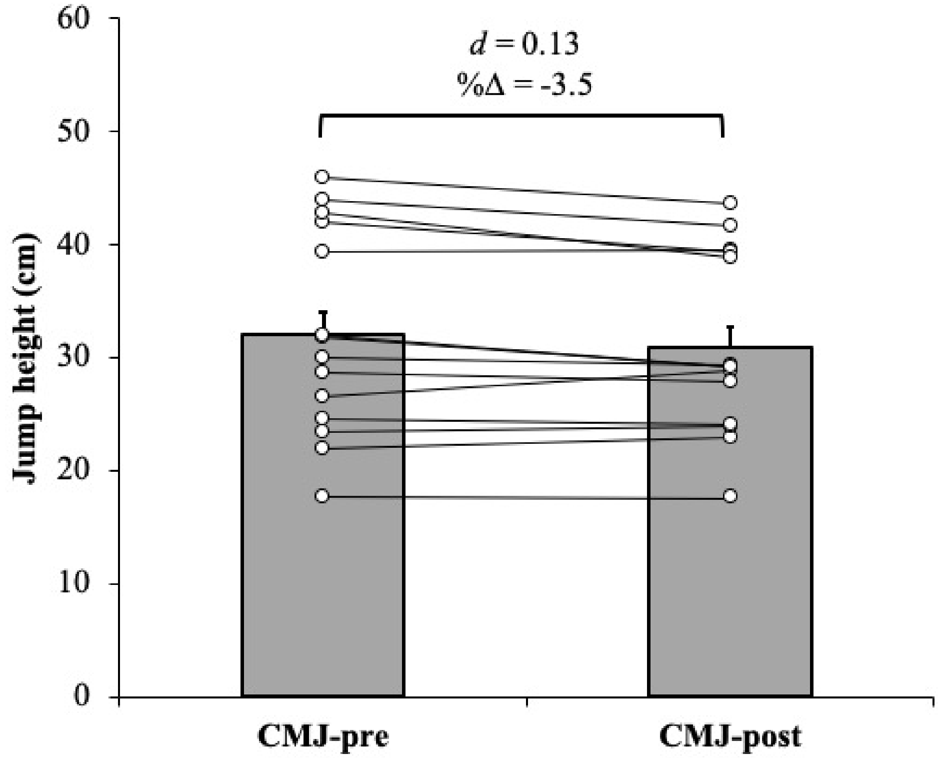

Figure 2 – Individual changes in jump height after the drop jump testing protocol. d, Cohen's d effect size ([CMJ-pre – CMJ-post]/SD both); %Δ, percentage differences ([CMJ-pre – CMJ-post]/CMJ-post x 100). Data are mean ± error standard of measurement.

190x149mm (72 x 72 DPI)

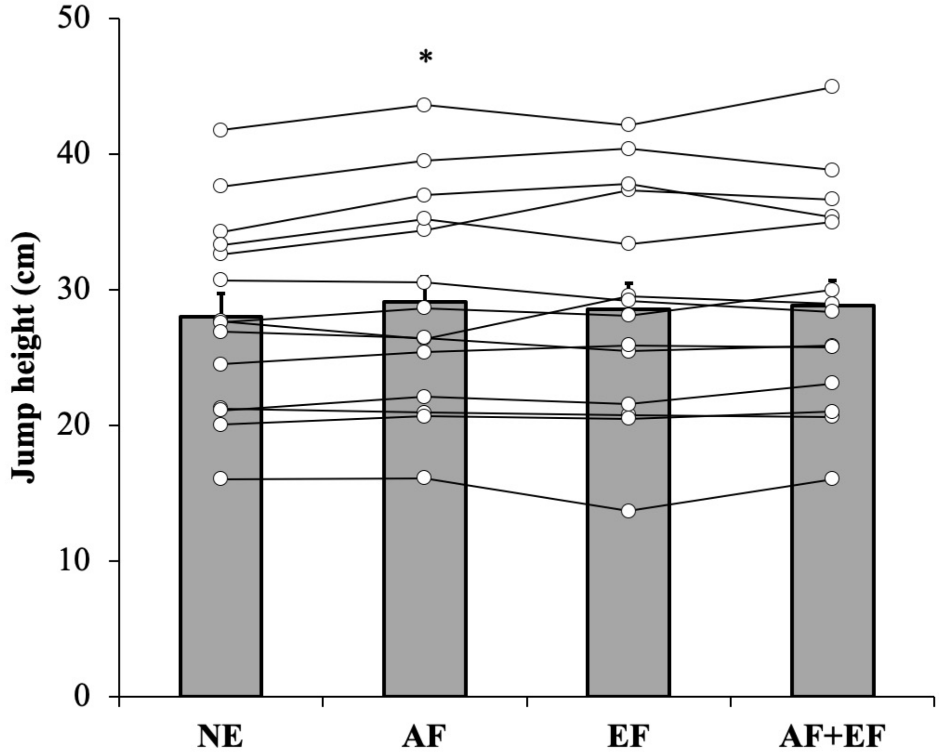

Figure 3. Individual comparisons of the drop jump height performance between different coaching conditions. NE, neutral; AF, augmented feedback; EF, external focus of attention. *, significant differences between the AF and NE conditions (p < .05; ANOVA with Bonferroni correction). Data are mean ± error standard of measurement.

189x149mm (144 x 144 DPI)